BUSITEMA UNIVERSITY
Pursuing Excellence

FACULTY OF ENGINEERING

DEPARTMENT OF MINING AND WATER RESOURCES ENGINEERING

FINAL YEAR PROJECT REPORT

"RE-DESIGNING QUARRY SLOPE BY NUMERICAL MODELLING."

CASE STUDY: SEYANI INTERNATIONAL COMPANY LIMITED QUARRY

P.O BOX 23067, Kampala-Uganda

BY:

NAME: OKELLO JONATHAN.

REG. NO: BU/UG/2014/2028

CONTACT: +256751030427, +256777553202, +256790633110

E-mail: Jonathanokello46@gmail.com

SUPERVISORS: ENG. NASASIRA MICHEAL BAKAMA.

ENG. THOMAS MAKUMBI.

ENG. WANGI MARIO GODFREY.

Handed in to the Head of Department Mining and Water Resources Engineering in partial fulfilment of the Requirements for the Award of a Bachelor of Science in Mining Engineering.

May 2018

Abstract

Mining contributes considerably to the wealth of Uganda and the world as a whole, of which open pit quarrying has its fair share of contribution. The number of operating open mines/quarries is steadily increasing as compared to underground mines; this is due to low gestation period, higher productivity, and quick rate of investment. Open pit mining/quarrying is a mining method that involves design of rock slopes, which should remain stable for the duration of the mining. The economic impact of excessively conservative design or of failures in these slopes can be very large and every effort is required for an optimized design. slope failures of any kind, if not properly managed, can have an effect on production, result in loss of ore reserves, cause pit abandonment/premature closure of the mine, represents a safety hazard for mining personnel, which in extreme circumstances could result in loss of life.

Against this backdrop, there is a strong need for good practices in slope design and management to ensure timely, suitable corrective actions to minimize the slope failures. Rock slope failures are events controlled by natural physical processes.

In Uganda, most slopes designs depend on the field experience, rules of thumb with some sound engineering judgment and to a small extent using limit equilibrium and rock mass classification methods. Limit equilibrium methods deal with structurally controlled planar or wedge failures and circular or non-circular failure in homogeneous materials. Rock mass classification methods deal with the preliminary design phase when very limited rock mass data is available.

The aim of the project was to apply numerical modelling in design of slopes considering different rock properties (Alzo'ubi and Alzo 'ubi 2016). Developed numerical models using FLAC SLOPE.v5.00 for finding out the factor of safety. Varied the parameters for each slope and for each had the factor of safety calculated for each step. Correlated these values with the bench parameters to find out how the factor of safety changes with changing parameters.

Declaration

I, **OKELLO JONATHAN** REG. NO: **BU/UG/2014/2028,** do hereby declare with academic honesty that with the exception of work and quotes of other people, which I have fully referenced to and acknowledged herein, this report is the result of my own original research work. No part of it has been submitted in pursuit of another degree in this University or anywhere else.

Signature: _____

Date: 29 / 05 / 2018

Approval

This is to certify that the Final Project report entitled **"RE-DESIGNING QUARRY SLOPE BY NUMERICAL MODELLING"** submitted by OKELLO JONATHAN REG. NO: BU/UG/2014/2028 in partial fulfilment of the requirements for the award of Bachelor Science in Mining_Engineering at Busitema University is an authentic work carried out by him under supervision and guidance.

To the best of my Knowledge, the matter enclosed in this report has not been presented for the award of any Degree or Diploma or similar title of any University or Institution.

ENG. NASASIRA MICHEAL BYAMUKAMA

Signature: ..... Date: .....

ENG. THOMAS MAKUMBI.

Signature: ..... Date: 04/06/2018

ENG. WANGI MARIO GODFREY.

Signature: ..... Date: .....

Acknowledgement

First and fore most I want to acknowledge the Almighty God for to extend my sincere gratitude to the Almighty God for His unlimited grace and love upon my life up to this far in my studies.

In a special way, I would like also to thank my supervisors Eng. Nasasira Hillary, Eng. Nasasira Micheal Bakama, Eng. Wangi Mario Godfrey and Eng. Thomas Makumbi for the advice, guidance, encouragement and valuable suggestions offered in this study. This work would not have been possible without their encouragement and constructive criticism. I sincerely thank you for the time and patience you devoted for this work.

I am also thankful to all the faculty and departmental members for their valuable suggestions and not forgetting Mr. Tugume Wycliffe in particular.

Furthermore, I am thankful to the management of Seyani international quarry who bought my idea and allowed me carryout tests and sampling at their site. I cannot fail to mention of Mr. Odeke Joseph, Mr. Isanga Isaac, and Mr. Ronnie for their assistance from time to time and all the workers who stood by me.

My sincere appreciation also go to Makerere University – Department of Geology and Petroleum studies for allowing me use their Laboratory for my tests and in Particular, Mr. Sessanga Robert for the guidance during tests.

I would like to acknowledge the authors of different research paper referred in the work, which were a valuable source for understanding the subject.

Lastly, I would also like to express my appreciation to my friends and colleagues for the moral and physical support given to me in my endeavours to complete this piece of work.

The Almighty God should bless you abundantly.

Dedication

I dedicate this report to my family in appreciation for their selfless care and unflinching support provided to me since childhood, and for the spirit of hard work, courage and determination instilled into me, which attributes I have cherished with firmness and which have indeed made me what I am today.

May the Almighty God Bless the works of your hands.

Table of Contents

List of figures;

List of tables

List of Appendices

CHAPTER 1. INTRODUCTION

This chapter describes the background information of the project, the problem statement, significance, purpose, objectives and scope of the study. The problem statement describes the research problem and identifies potential causes and a solution. The significance describes the importance of the project. The specific objectives presented will achieve the main objective.

1.1 Background;

Mining contributes considerably to the wealth of Uganda and the world as a whole, of which open pit quarrying has its fair share of contribution. The number of operating open mines/quarries is steadily increasing as compared to underground mines, this is due to low gestation period, higher productivity, and quick rate of investment (Vaziri *et al.* 2010). Open pit mining/quarrying is a mining method that involves design of rock slopes which should remain safe for the duration of the mining (Keaton 2007). Design of rock slopes involves the determination of optimal bench angle, height of benches overall slope angle, optimal widths for spill berms and ramps (Er *et al.* 2015).

The economic impact of excessively conservative design or of failures in these slopes can be very large and every effort is required for an optimized design. Slopes need to be as steep as possible to minimize the amount of waste rock mined and hence to minimize mining cost, but the economic consequences of failure of slopes due to over-steepening can be disastrous. Factors taken into account in the design of rock slopes are the geological structure, ground water conditions, blasting practice, slope plan geometry and seismic activity of the area (Contreras 2015).

In addition, slope failures of any kind, if not properly managed, can have an effect on production, could result in loss of ore reserves, can cause pit abandonment/premature closure of the mine, represents a safety hazard for mining personnel, which in extreme circumstances could result in loss of life. On large scale it may also affect the surface surrounding the open excavation, which may involve structures and infrastructure (Stacey *et al.* 2003).

Rock slope failures are however, events controlled by natural physical processes. Geological geotechnical models that can be used to understand and to analyse these processes often include structural data as well as information on lithology,

WORKS CITED

Alzo'ubi, A.K., Alzo 'ubi, A.K. (2016) 'Rock slopes processes and recommended methods for analysis', *International Journal of GEOMATE*, 11(3), 2520–2527, available: http://www.scopus.com/inward/record.url?eid=2-s2.0-84958213930&partnerID=tZOtx3y1.

Ayodele, A.S., Bello, W.A. (2014) 'Slope Stability Analysis of Bench in Complete Construction Solid Concentrate (Quarry) Limited , Ilorin , Nigeria', (1981), 235–243, available: https://www.imwa.info/docs/imwa_2014/IMWA2014_Agbalajobi_235.pdf [accessed 12 Sep 2017].

Bahadori, A., Vuthaluru, H.B. (2009) 'Prediction of bulk modulus and volumetric expansion coefficient of water for leak tightness test of pipelines', *International Journal of Pressure Vessels and Piping*, 86(8), 550–554.

Bieniawski, Z.T. (1989) 'Engineering rock mass classifications : a complete manual for engineers and geologists in mining, civil, and petroleum engineering', *Engineering rock mass classifications : a complete manual for engineers and geologists in mining, civil, and petroleum engineering*.

Bieniawski, Z.T. (1994) 'Reviving the mission of rock mechanics teaching in mining and civil engineering', *International Journal of Rock Mechanics and Mining Sciences and*, 31(2), 135–142.

Contreras, L.F. (2015) 'An economic risk evaluation approach for pit slope optimization', *Journal of the Southern African Institute of Mining and Metallurgy*, 115(7), 607–622.

Delaney, G.W., Morrison, R.D., Sinnott, M.D., Cummins, S., Cleary, P.W. (2015) 'DEM modelling of non-spherical particle breakage and flow in an industrial scale cone crusher', *Minerals Engineering*, 74, 112–122.

Dellar, P.J. (2001) 'Bulk and shear viscosities in lattice Boltzmann equations', *Physical Review E - Statistical Physics, Plasmas, Fluids, and Related Interdisciplinary Topics*, 64(3), 11.

Er, S., Yılmaz, M., Tugrul, A., Ertin, A., Tokgöz, N., Arel, E. (2015) 'Assessment of slope stability problems in an open pit quarry; an example from Istanbul Cebeci Region, Turkey', in *Engineering Geology for Society and Territory - Volume 2: Landslide Processes*, 2097–2100.

Ghosh, S., Günther, A., Carranza, E.J.M., Van Westen, C.J., Jetten, V.G. (2010) 'Rock slope instability assessment using spatially distributed structural orientation data in Darjeeling Himalaya (India)', *Earth Surface Processes and Landforms*, 35(15), 1773–1792.

Harmer, R.E. (2000) 'MINERALISATION OF THE PHALABORWA COMPLEX AND THE CARBONATITE CONNECTION IN IRON OXIDE-Cu-Au-U-REE DEPOSITS', *Porter, TM, Hydrothermal Iron Oxide Copper-Gold & Related Deposits: A Global Perspective*, 1, 331–340.

Hoek, E. (2002a) 'Hoek-Brown failure criterion-2002 edition', *5th North American Rock ...*, 1, 267–273, available: http://www.rockscience.com/assets/files/uploads/7715.pdf.

Hoek, E. (2002b) 'A brief history of the Hoek-Brown criterion', *Program:" RocLab", URL: http://www. rockscience. com*, 33(3), 1–7, available: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Brief+history+of+the+Hoek-Brown+criterion#1.

Hoek, E. (2009) 'Fundamentals of slope design', *Slope stability 2009*, (November), 9–11.

Jing, L., Hudson, J.A. (2002) 'Numerical methods in rock mechanics', *International Journal of Rock Mechanics and Mining Sciences*, 39, 409–427.

Keaton, J.R. (2007) 'Rock Slope Engineering: Civil and Mining, 4th Edition', *Environmental and Engineering Geoscience*, 13(4), 369–370.

Kourkoulis, R., Gelagoti, F., Anastasopoulos, I., Gazetas, G. (2011) 'Slope Stabilizing Piles and Pile-Groups: Parametric Study and Design Insights', *Journal of Geotechnical and Geoenvironmental Engineering*, 137(7), 663–677, available: http://ascelibrary.org/doi/10.1061/%28ASCE%29GT.1943-5606.0000479.

Krahn, J. (2003) 'The 2001 R.M. Hardy Lecture: The limits of limit equilibrium analyses', *Canadian Geotechnical Journal*, 40(3), 643–660, available:

http://www.nrcresearchpress.com/doi/abs/10.1139/t03-024.

Kumacheva, E., Klein, J. (1998) 'Simple liquids confined to molecularly thin layers. II. Shear and frictional behavior of solidified films', *The Journal of Chemical Physics*, 108(16), 7010–7022, available: http://aip.scitation.org/doi/10.1063/1.476115.

Laloui, L., Ferrari, A., Li, C., Eichenberger, J. (2016) 'Hydro-mechanical analysis of volcanic ash slopes during rainfall', *Géotechnique*, 66(3), 220–231, available: http://www.icevirtuallibrary.com/doi/10.1680/jgeot.15.LM.001.

Lu, L., Wang, Z.J., Song, M.L., Arai, K. (2015) 'Stability analysis of slopes with ground water during earthquakes', *Engineering Geology*, 193, 288–296.

Maleki, M.R., Mahyar, M., Meshkabadi, K. (2011) 'Design of Overall Slope Angle and Analysis of Rock Slope Stability of Chadormalu Mine Using Empirical and Numerical Methods', *Engineering*, 03(09), 965–971, available: http://www.scirp.org/journal/PaperDownload.aspx?DOI=10.4236/eng.2011.39119.

Mouflis, G.D., Gitas, I.Z., Iliadou, S., Mitri, G.H. (2008) 'Assessment of the visual impact of marble quarry expansion (1984-2000) on the landscape of Thasos island, NE Greece', *Landscape and Urban Planning*, 86(1), 92–102.

Rai, P., Schunnesson, H., Lindqvist, P.A., Kumar, U. (2016) 'Measurement-while-drilling technique and its scope in design and prediction of rock blasting', *International Journal of Mining Science and Technology*, 26(4), 711–719.

Sarkar, S., Kanungo, D.P., Kumar, S. (2012) 'Rock Mass Classification and Slope Stability Assessment of Road Cut Slopes in Garhwal Himalaya, India', *Geotechnical and Geological Engineering*, 30(4), 827–840.

Schön, J.H. (1996) 'Electrical Properties of Rocks', in *Physical Properties of Rocks*, 379–478.

Sousa, L.M.O. (2007) 'Granite fracture index to check suitability of granite outcrops for quarrying', *Engineering Geology*, 92(3–4), 146–159.

Stacey, T.R., Terbrugge, P.J. (2000) 'Open pit to underground — transition and interaction', *MassMin 2000 : 29 October-2 November 2000, Brisbane, Queensland*, (November), 97–104.

Stacey, T.R., Xianbin, Y., Armstrong, R., Keyter, G.J. (2003) 'New Slope Stability Considerations for Deep Open Pit Mines', *Journal of The South African Institute of Mining and Metallurgy*, 103(6), 373–390, available: http://www.saimm.co.za/Journal/v103n06p373.pdf.

Starfield, A.M., Cundall, P.A. (1988) 'Towards a methodology for rock mechanics modelling', *International Journal of Rock Mechanics and Mining Sciences and*, 25(3), 99–106.

Stead, D., Eberhardt, E., Coggan, J. (2006) 'Developments in the characterization of complex rock slope deformation and failure using numerical modelling techniques', *Engineering Geology*, 83(1–3), 217–235, available: http://linkinghub.elsevier.com/retrieve/pii/S0013795205002310.

Stead, D., Eberhardt, E., Coggan, J., Benko, B. (2001) 'Advanced Numerical Techniques in Rock Slope Stability Analysis – Applications and Limitations', in *LANDSLIDES – Causes, Impacts and Countermeasures*, 615–624.

Topal, T. (2007) 'Discussion of "A new approach for application of rock mass classification on rock slope stability assessment" by Liu and Chen, Engineering Geology, 89:129-143 (2007)', *Engineering Geology*, 95(3–4), 99–100.

Trivedi, R., Vishal, V., Pradhan, S.P., Singh, T.N., Jhanwar, J.C. (2012) 'Slope stability analysis in Limestone mines', *International Journal of Earth Sciences and Engineering*, 5(4), 759–766.

Vaziri, A., Moore, L., Ali, H. (2010) 'Monitoring systems for warning impending failures in slopes and open pit mines', *Natural Hazards*, 55(2), 501–512.

Wortman, J.J., Evans, R.A. (1965) 'Young's modulus, shear modulus, and poisson's ratio in silicon and germanium', *Journal of Applied Physics*, 36(1), 153–156.